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Transforming power: Social science and the politics of energy choices

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ABSTRACT

This paper addresses key implications in momentous current global energy choices – both for social science and for society. Energy can be over-used as a lens for viewing social processes. But it is nonetheless of profound importance. Understanding possible 'sustainable energy' transformations requires attention to many tricky issues in social theory: around agency and structure and the interplay of power, contingency and practice. These factors are as much shaping of the knowledges and normativities supposedly driving transformation, as they are shaped by them. So, ideas and hopes about possible pathways for change – as well as notions of 'the transition' itself – can be deeply constituted by incumbent interests. The paper addresses these dynamics by considering contending forms of transformation centring on renewable energy, nuclear power and climate geoengineering. Several challenges are identified for social science. These apply especially where there are aims to help enable more democratic exercise of social agency. They enjoin responsibilities to 'open up' (rather than 'close down'), active political spaces for critical contention over alternative pathways. If due attention is to be given to marginalised interests, then a reflexive view must be taken of transformation. The paper ends with a series of concrete political lessons.

1. Transformation and power

The advent of this journal is propitious. And this is not just for the relatively small community of researchers engaged specifically in social scientific study of energy systems. There has long been recognition for the role of social research in energy studies [1] and there can be little doubt of its importance [2]. But the reverse is also true. Of the many expediently segregated – but intimately interconnected [3,4] – functional 'sectors' of socio-economic life (like water, food and shelter), there is also a sense in which none are more significant to general development of social science at large – or indeed society itself – than is 'energy' [5–7].

It is the 'energy sector', after all, that currently stands most momentously at a historic "crossroads" [8]: wrangling over a prospective globally concerted transformation away from fossil carbon infrastructures [9,10]. This is not just an intractable technical undertaking [11]. It is also a monumental cultural and political challenge [12], with outcomes highly sensitive to disparate imaginations of the world and of the place of humanity within this [13,14]. The subjective perspectives under which these issues are analysed and understood, can be as important as the objective developments themselves [15]. However viewed, though, a conjunction of extraordinary pressures is briefly opening a rare 'window of opportunity' [16], through which the re-structuring of large-scale, long-lived 'sociotechnical regimes' may be unusually sensitive equally to human agency and historical contingency [17].

So, contemporary developments specifically bearing on the energy sector, may in complex, nonlinear ways help yield potentially profound importance for the more general constituting of future global societies [18]. And understandings of these social dynamics and their possible consequences and drivers depend on – and carry under-appreciated implications for – some of the most fundamental themes in social science as a whole [15,19]. These include: relations between agency and structure; the shaping of knowledges and normativities and the interplay of power, contingency and practice [20]. Here, as elsewhere, it may be that the most rigorously formative influences on academic activity and the quality of the results, might not be the 'internal' procedures of institutionalised disciplines, but the 'external'

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transdisciplinary challenges of sincere efforts to effect real-world change [21,22].

At the outset, then, this raises demanding questions over what in this context might be meant by 'power'. One way or another, it is through various kinds of power dynamics, that any social transformation comes to be realised or suppressed [23]. But power is a notoriously slippery concept, which deserves to be clarified right from the start. In colloquial terms, power is about the exercise of some form of social control [24]. But 'control' is barely less enigmatic [24,25] – also introducing immediate queries over the constituting and bounding of chains of causes, consequences, intentions and collateral effects [26]. In what sense might long run energy futures meaningfully be considered a category even susceptible to 'control' [27,28]? If so, where does the buck stop in tracing drivers and implications [29]? Under what notions of intentionality [30]? And who is the 'we' doing the controlling [31:186]? After all, when has humanity as a whole even undertaken – let alone controlled, still less achieved – any single explicitly and collectively deliberate end at all?

Even in relatively straightforward organisational settings, simple deterministic pictures of control can be problematic. And they are often better understood more as instrumental fictions necessary for the assertion of privilege, than as disinterested accounts of actuality [32–36]. When stripped of this expediency, many real-world instances of 'control' can decompose into complex conditions of diverse mutually adapting intentionalities and (in)tractabilities. And the possibilities of many alternative accountings for causality among proliferating multitudes of nested implicated factors, leaves any particular tracing of control significantly in the eye of the beholder [37]. In energy futures as elsewhere, then, care must be taken that analysis of social dynamics does not – under instrumental pressure of patronage to "see like a state" [38] – simply entrench and perpetuate misleading 'fallacies of control' [39]. Such reinforcing of incumbency can all-too-easily lead to the opposite of transformation.

This is at least as true in wider governance, as it is within organisations [35,40]. And, crucially, it applies as much when contemplating the exercise of democratic, as of autocratic, power in 'social control' [28]. In other words, even in the constituting of the concepts themselves, incumbency has a habit of subverting understandings of 'power' and 'control' [41,42]. History provides many examples where ostensibly revolutionary efforts to overturn incumbency simply reproduce it in another form – often more entrenched [43–45]. If it is to help effect real socio-political change of the depth and scale envisaged, then, serious consideration of the social dynamics of energy transformation, should not fall into this trap.

In order to address these difficulties, then, 'power' might better be addressed in a more nuanced and qualified guise: as 'asymmetrically structured agency'. Here, 'agency' refers to the many different kinds of capacity involved in shaping and performing (rather than controlling) social action [24]. Such asymmetries are constituted by diverse distributions in many social modes [46], media [47], levels [48], relations [49,50], fields [51] and forms of capability [52]. In all these senses, though, agency (and so power) can be recognised as inherently more dynamic, relational and distributed, than it is specifically located [53]. And there are recursively co-constituting – i.e.: "reflexive" [54] – relations with intentionality [55], discourse [56], normativity [57] and political and economic interests [58]. It is these that make so problematic, any simple notion of deliberately controlled social transformation.

So, this understanding of power as asymmetries in flows of social agency has important practical implications for global energy transformation. And these are as salient to understandings, intentions and discourse about change, as to the effecting of change itself. The implicated forms of agency are not singular and controlling, but complex and multidimensional; reflexively conditioning the supposedly driving knowledges and motivations [59]. And the frequently knotty contours in these eddying flows of agency [60], mean that incumbency encounters many ways to subvert the constituting of change. So, ostensibly novel 'transitions' may readily end up concealing what are in actuality, deeper realignments with existing structures. In other words, the realised forms of 'transformation' may be more discursive and superficial than material and substantive. The more radical and challenging the attempted transformation, the greater this propensity to subversion [61]. Concrete examples (discussed further below), include ways in which pressures for 'sustainable' energy transformation driven primarily by interest in renewable energy, might yield instead, transitions to nuclear power or climate geoengineering. Seeking to effect social transformation is a Faustian dance. Power is necessary for transformation, but this may be subverted if power itself is not transformed.

These are thorny challenges – familiar in colloquial discussion, but curiously neglected in analysis. The present paper can grapple only with a few. Some of the more profound issues will be returned to at the end. For now, discussion will pick up in a more prosaic way. First, it will set the stage for discussing currently mooted energy transformations, by reviewing the intimate general relationships between 'energy systems' and wider social orders. Then, it will turn to some of the entrenched structurings of Modernity – as a particular social form – and the crucial place within this of energy technologies (especially nuclear power). From here, attention will focus on a crucial way in which incumbent interests impede transformation in this sector – constraining and conditioning what counts as 'reliable knowledge' about possible energy pathways. This yields some concrete findings concerning the conduct of social science in relation to energy policy.

These findings will in turn lead to an array of important wider implications for general relations between science and democracy as means to help effect substantive (rather than rhetorical) transformation. The penultimate section will return to the dilemmas and contradictions of power and control sketched above – and urge a more reflexive approach to their reconciliation. In the end, it will be argued that real transformation in global energy institutions and infrastructures – like any radical social change more generally – requires transformation in the 'knowing and doing' of power itself. Although quite general in their scope, these conclusions underpin a very specific set of practical political recommendations of direct relevance to the social science of energy.

2. Energy and society

In contemplating the magnitude of the current struggles for global energy transformations, it is important to recall – with other papers in this issue [62–65] – that earlier realised cultural, infrastructural, political and economic transformations have also been profound [66]. And easily forgotten, is that secular rates of change have also frequently been formidable [67,68]. Cumulative infrastructure developments are often as formative in their effects as wholesale substitution [69]. But few previous structural shifts have been as historically rapid or socially pervasive as those now envisaged for global energy transitions [70]. Nor – crucially – have they aspired to the same depth or extent of explicitly shared social intentionality or assertively coordinated political control. It is in the associated discursive pressures to emphasise the need for (and claim and appropriate) such control, that there arise the dangers of the instrumental fallacies discussed above.

Challenges of global energy transformations, then, are not just on a significantly greater scale, but also arguably of a radically

different order to any previous deliberately concerted political undertaking. It is worth reflecting on the empowering audacity of this ontological novelty, before wringing hands too despairingly over the oppressive difficulties bearing on current efforts to achieve it. In the absence of deliberate reflection on this point, it is not just political rhetoric, but the fabric of knowledge and expectations themselves, that can become vulnerable to expediency and manipulation. For instance, many forms of anti-transformative inertia and self-interest in incumbent energy regimes [71], are already impacting in deep and strong ways on understandings of two radically contrasting forms of prospective global 'transformation' – respectively 'progressive' and 'conservative' with respect to entrenched regime interests.

The 'progressive' transformation (reviewed further below) would harness diverse proven viable global renewable resources and innovations to deliver energy services at the same time as eliminating carbon emissions and realising other Sustainability benefits [70,72–78]. The alternative 'conservative' transformation, by contrast, would use an array of speculative technologies and unprecedented global institutions aimed solely at assuming human 'control' over the planetary climate [79–82]. Although requiring economic and political investment on a scale similar to that required for direct transformation of energy infrastructures, most forms of climate geoengineering would leave energy needs entirely unaddressed [83,84]. Yet, it is this manifestly more speculative alternative, that is gaining strikingly increasing high-level worldwide attention [85]. That a conservative transition built around climate geoengineering is thought in some quarters to present a somehow more tractable governance challenge to a progressive transformation based on renewable energy [86,87], is an indication of the strength of entrenched vested interests in this sector. Their asserted agencies are not just restricted within a particular regime, but also leave an imprint on more general patterns of policy knowledge and political expectation [88,89]. The result is an especially pertinent example of the kind of expedient fallacy of control described at the beginning of this paper [39]. There seems here a particular role for social science in facilitating more reasoned reflection on these issues [90,91].

These are the kinds of issue that arise in contemplating the long run relationships between energy systems and global societies at large. There is, however, a need for critical caution. Hyperbolic claims concerning energy and society are nothing new. Discussions of energy futures seem especially prone to misleading simplification and intellectual hubris [92]. So it is worth asking before proceeding, whether 'energy' really is so distinctively important as a lens through which to engage with wider social dynamics? Of course – as mentioned above – the material significance of energy in society is longstanding [93] . . . and long recognised [94,95]. But this is also true of other essential material functions in human life – for instance, around water, food and shelter [96]. Yet as well as being profoundly interlinked [97], the social specificities of energy-related flows and structures in the contemporary world are arguably even more formative and foundational than in these other 'sectors'.

Energy dynamics feature especially prominently in many understandings of past processes of structural emergence [98] and 'collapse' [99]. And it is contemporary systems for global energy provision, that are arguably most implicated at the grandest of scales in "fuelling capitalism" [100], as well as in the most intimate details of everyday lives [101,102]. The particular cultural formativities of energy are thus distinguished not just in the sheer magnitude and imperative necessity of its diverse roles, but in the ways in which patterns and practices in production and consumption implicate social agency and structure in distinctively specific forms. So, it is perhaps in relation most to practises around energy services that a proverbial time-travelling Pleistocene human ancestor might arguably experience their most bewildering surprises in the everyday materialities of social life across much of the world.

Be this as it may, great care must still be taken over many kinds of 'energy exceptionalism'. It is clear that disciplinary fashions and privileges can help drive overly promiscuous recourse to energy as a source of metaphor and metonym in social science. Energy productivity is implicated in some of the most inflexible determinisms and disabling simplifications of historical materialism [53,103–105]. Energy is arguably disproportionately prominent equally in theories about cultural evolution [106–108], political ecology [109,110] and social action [111]. And with respect to historical dynamics and social orders in general, few themes are more prolifically invoked than energy, as grounds for reductive determinism or essentialist reification [112]. Especially in the language of entropy, ambitious efforts at energy-based social explanations are widespread in anthropology [113,114], archaeology [115–117], economics [118–123], agronomics [124], industrial and social ecology [125–128], sociology [129], management [130–132], politics [133–135], the arts [136], history [137] and futurology [138]. If anything, the problem is more that explanatory potentials for energy-based concepts in social understandings are overstated, than that they are neglected.

3. Modernity and technology

But there exist more particular reasons for attention to the nexus between energy research & social science. These rest more in addressing discursive, cultural and political attributes of energy systems, than their general physical parameters. They arise in a different aspect of the current historical juncture of energy choices with which this paper began. For, it is also in the energy arena that narratives of Modernity have played out what is arguably their most formative dynamics [139]. Half a century ago, the worldwide rise of nuclear power provided a leitmotif for post-war Modernity [140,141]. But more recent drastic relative decline in global nuclear fortunes offer an equally iconic disruption of this story [142]. There is of course much complex detail in many divergent settings. But the bottom line is pretty clear. In order to appreciate this, it is necessary to take a few steps back and consider the historical bigger picture.

Technology in general is central to contested notions of Modernity over the past century and a half [139]. In a stylised 'Enlightenment' account [143], technological progress is presented simply as an emergent outcome of incumbent social structures and dynamics. Whatever innovations are produced under prevailing patterns of power and privilege, come to be recognised uncritically as 'progress' [144]. Ignoring the manifest roles of contingency, path dependency and channelling by power [145–152], technical advance therefore tends to be defined in specific 'sectors', tautologously and teleologically by reference to those particular configurations that happen to arise.

Ironically, the hegemonic persistence of this 'Whig' [153] 'myth of progress' [154,155], is due in large part to the depth of its own error. So irrevocably and ubiquitously have successive sociotechnical regimes typically become entrenched (in areas like agriculture, transport, communications, manufacturing and war – as well as energy), that it is difficult to imagine any plausible counterfactual under which large scale trajectories might have oriented in alternative directions [156]. So, the potent singularity of this 'one-track' 'race-to-the-future' 'Enlightenment' imagination, is itself arguably one of the prime forces in this entrenchment [157]. In other words,

the magnitude of the fallacy exerts a self-reinforcing effect. It is against this background, that it can be seen that the history of nuclear power presents a starkly disruptive picture, moving from early success as a synonym of Modernity [140], to later failure as a potentially destabilising antonym.

Right from the outset, nuclear power has been more than just one sectoral instance of a supposed 'race to the future', pursued by means of a single narrowly privileged technological trajectory. For a long time, nuclear technology was in many ways emblematic of this general syndrome [139]. Realisations of wartime military ambitions for nuclear technologies were formatively horrific [158,159]. These engendered intense guilt-driven idealistic counter-reactions in influential quarters of many scientific communities – around beating 'swords into ploughshares' for 'atoms for peace' [160]. But the incentives also intensified, to establish infrastructures for nuclear weapons and military propulsion [161–163]. These ostensibly contending cultural forces then in turn interacted synergistically to help nurture a vigorous early elite 'nuclear discourse' in many countries, in which nuclear prowess became intensely associated with national identity [141,140].

This potent cultural brew in turn reinforced exuberant expectations and massive institutional and material investment in civil nuclear power during the 1950s and 1960s. And it was this that, in many contexts, led nuclear power quickly to consolidate its status as the most canonical exemplar of Modernity [140]. More material path-dependent increasing returns also set in, to help channel very specific technological trajectories based around design traditions initially optimised for submarine propulsion or plutonium production [164]. Each was (and remains) equally poorly suited to maximising goals of safe or economic civilian power production [165]. It is significant that these manifestly sub-optimal reactor designs should persist and become so effectively irreversible within global nuclear supply chains. This is especially so, given that decision making processes in this sector were claimed (and widely viewed), as the epitome of synoptic rationality [166]. That nuclear power was backed in this period by such enormous economic, political and cultural resources, should (on the face of it) have allowed more latitude for escaping such closure [167]. For such 'lock-in' nonetheless to take place, then, simply shows the importance of contingency and power – even in the most deliberate and concerted of policy programmes. This alone is a highly relevant lesson for contemporary challenges around climate change – where the burgeoning profile of climate geoengineering raises (as mentioned above) potentially similar dynamics.

Also of current topical relevance for climate change debates, is that it was this same continuing general hegemonic profile, that helped attract to nuclear power from the later 1960s, some equally iconic reactions on the part of ostensibly 'anti-modernist' – or reflexively modern [168] – global social movements around environment, peace and social justice [169]. As a result, from the 1970s, the formidable discursive, institutional and infrastructural stabilities hitherto accumulating around nuclear technology, suffered a remarkable international destabilisation. Early processes of increasing returns were countered by even greater negative feedbacks, as defensive regulatory responses to political opposition revealed and exacerbated previously concealed diseconomies [170].

These negative effects were then further amplified by a succession of nuclear accidents – of kinds previously officially denied even as realistic prospects [171]. Together with the increasingly manifest intractabilities of nuclear waste management [172], these forces were reinforced in the 80s by a growing intolerance for concealed uncompetitiveness, fostered by a new political economy of liberalisation [17]. In short, over the space of just three decades, the early ballistic ascendancy of nuclear power went into equally meteoric reverse. Arguably in no other area of the history of technology, is there a conjunction of such apparently rapid and revolutionary global emergence, followed so quickly by potentially equally transformative decline [173,174]. Discomfited by the misfortunes of this prodigal offspring, it seems in the energy 'sector' that the defining "one-track race" of Modernity first tripped up [143,175].

4. Power and knowledge

In seeking to understand these mutually profound implications between developments in the energy field and issues of wider salience in social science, it is worth considering the specific dynamics around nuclear energy in a little more depth and detail. Of particular relevance, is that they illustrate the crucial roles played by incumbent patterns of power and privilege, not only in constituting social, economic and technical 'regimes' as objects of scrutiny, but also in configuring the subjective social processes through which these regimes are more widely scrutinised and understood [176]. And this is a lesson not lost on those for whom influence and stakes are highest – or who enjoy most privileged access to the means of this shaping. Few of these means are more powerfully self-fulfilling, than the ways incumbent interests configure 'scientific' knowledges such as to condition wider social expectations over what is 'realistic' or 'unrealistic' as directions for technological change [177]. The overall, effect can be a powerful circular reinforcement of incumbency.

The momentous energy choices with which this chapter began, offer a particularly good example of this. With climate change now widely held to present an over-riding imperative, hegemonic patterns of knowledge in other areas are being systematically reconfigured [178]–perhaps most notably with regard to nuclear power. Problems of radioactive waste management, nuclear weapons persistence and proliferation, chronic uncompetitiveness and periodic catastrophic accidents all remain obstinately unresolved [179]. Of course, optimistic claims remain. Perhaps they may yet be borne out [180]. But the persistence of these challenges – each dating back to the origins of nuclear power – is irrefutable [181]. Either way, whether by deliberate agency or more distributed realignment, it seems that the orthogonal advent of widespread general concerns over climate change is in many ways and quarters re-conditioning much more specific 'scientific' understandings of technical nuclear issues. Whatever the balance of strategy and contingency, it is clear that tactical narratives around a prospective global "nuclear renaissance" are significantly reinforced [180,182].

The most conspicuous impact of these dynamics, lies in high level policy debates over current energy choices. Indeed, the fact of this being a 'choice' at all is often exactly the point at issue. Although the challenges of a 'zero carbon' energy transition are undoubtedly ambitious and daunting, it is clear that there exists a diversity of possible pathways through which to address them [183]. The obstacles to an entirely renewable global energy system are not – as often claimed [184–186] – about intrinsic limits on resources, technologies or economics [17,187–195]. Repeated detailed assessments show that the energy service needs of a more heavily populated and equitable world enjoying radically higher levels of wellbeing, can be cost-effectively met (in dynamic terms [196,197]) entirely and solely through diverse currently available technological and organisational innovations around wind, solar, biomass, hydro, ocean and geothermal power [70,72–78].

Though much room remains for argument over details, there can be little doubt that transformations in global energy services

based entirely around renewables are at least realistic in the sense that these trajectories are in principle technically practicable, economically feasible, socially viable – and so potentially historically realisable. Indeed, it is precisely the anticipation of this prospect that helps underpin the current ambitious commitment by the world's arguably most successful industrial economy, Germany, to undertake the possibly globally catalytic '*Energiewende*' [198–201].

Of course, the mere possibility of a wholesale global move to renewable energy does not mean that such a transition is therefore automatically to be supported – still less that it will occur. As with other essentially political ends in plural societies, it is equally possible legitimately to propound (or contest) either a renewable or nuclear-based global energy vision. Under contrasting values and perspectives, either might be considered normatively desirable – or on balance preferable. And – despite some intrinsic incompatibilities – there also exist many different kinds of diverse mix [202]. But what is clear, is that the overall industrial, infrastructural and operational implications of broadly contrasting visions for nuclear and renewable-based zero carbon energy infrastructures are so disparate, that real-world energy systems cannot be ***optimised*** simultaneously around both pathways [203]. Despite the latitude for diversity, then, there emerges significant scope for social – and therefore political – choice.

This is where there arises a remarkable further indication of the effects of power on knowledge. For it remains the case that in many energy policy debates (notably outside Germany), the fact of this choice is frequently not only side-lined in the 'evidence base' constituted by high-level policy documentation, it is sometimes effectively excluded. Around the world, official studies persistently present the achieving of a low carbon energy future not as a matter of social choice across divergent options, values, interests and preferences, but as a far more constrained and technical matter. In the UK, for instance, a historic fixation with nuclear power is especially entrenched, exerting unusually heavy influence over central government policy [204]. This is surprising, since the scale of nuclear generation in the UK remains relatively small compared to Germany (both in relative and absolute terms) – and the nuclear supply chain is far less developed or successful on the international stage [179,205]. The UK renewable resource is also more favourable [76,201]. Yet it is in the UK that nuclear interests seem to have exerted some of the most constraining effects on national energy policy. That so much more progress towards an alternative transformation should be made in a country where the success of the national nuclear industry might have been expected to make this vested interest so relatively strong, seems a significant indication of the comparative quality of post-War German democracy.

Be this as it may, it is informative to consider a little empirical detail here. In a rapid succession of detailed UK Government analyses conducted between 2002 and 2006, two early White Papers unprecedentedly highlighted the feasibility and viability of strategies based around renewables and energy efficiency [206,207]. Nuclear power itself was specifically identified as "unattractive" (207:12;44;61). But the leadership of the then UK Labour Government reacted by rejecting their own commissioned analysis, quickly convening instead a third, more superficial, 'review' in order to reinstate the nuclear option [208]. When this was itself later overturned by a judicial review on grounds of various procedural inadequacies [209], the Prime Minister remarked that any such further appraisal "*won't affect the policy at all*" [210]. The disjuncture between the material actualities of choice and the political construct of closure, could hardly be more stark. It is in these ways, that assertively pronounced expectations by powerful actors (within, as outside, government), may aspire to be self-fulfilling.

Also revealing are the positions over this period of the most relevant senior officials. For instance, UK Government Chief Scientist Professor Sir David King repeatedly asserted throughout, an exclusive and unqualified position summarised (in a title for one of his high profile newspaper commentaries): "*we have no alternative to nuclear power: if there were other sources of low carbon energy I would be in favour, but there aren't*" [211]. On occasions when directly confronted with evidence that, though he may not personally prefer them, viable alternatives do manifestly exist, King would quickly retreat to an argument that nuclear is still essential simply because "*we need to do everything*" [212]. And when this somewhat non-specific defence was further challenged, to the effect that a range of diverse mixes might (if so chosen), also readily entirely omit the nuclear option [183], the partisanship became even more evident – in a transparently teleological "*we need to keep the nuclear option open*" [213].

Again, this manifestly circular argument graphically illuminates the way in which authoritatively asserted 'scientific' knowledges can have the effect of asymmetrically emphasising particular favoured pathways at the expense of others. It confirms that the obstacles to transformative change are manifestly more institutional and cultural (and epistemic and normative), than they are material or technical [214]. And this realisation in turn further highlights the depth of the wider social transformations that are entailed [11]. It also underscores that these are as much about transformations of knowledges and imaginations about society, as they are about modifications to the material world. For social science and political action alike, then, energy transformation presents an especially crucial challenge.

5. Analysis and action

These are some key aspects of the momentous conditions referred to at the beginning, attending the emergence of this journal. And it is on this basis that it can be argued that the significance of these debates extends beyond the relevance of social science for energy studies, to encompass the important ramifications of energy politics for social science at large. So what do these implications entail most concretely? It would be impossible fully to do justice to this topic in a single article. Many themes are touched on in accompanying papers in the present issue [215–220]. In further editions of this journal, a diversity of wider repercussions will doubtless unfold. For the moment, the present paper will conclude by surveying a few of the more clear among the immediate challenges highlighted for social research.

First, the underqualified expressions of energy expertise reported in the above UK case, raise a general issue around 'speaking truth to power'. This is particularly acute for policy appraisal in the energy sector, because this field has been especially important in the development and application of prescriptive methods in quantitative social science [221,222]. And the resulting bodies of knowledge have in turn been particularly influential in encouraging widespread conceptualisations of politics in general as a process of 'rational choice' [223]. Such thinking has most recently come to prominence in the worldwide spread of rhetorics around 'new public management' [224,225] and 'evidence based policy' [226,227]. Yet across the underlying disciplines of neoclassical economics, operations research and decision analysis, shared foundational theory concerning exactly this kind of formal expert 'rationality' in social choice, has actually earned Nobel Prizes by showing through painstaking logical deduction, that its own underpinning axioms are significantly in tension [228–230].

In other words, it follows from precepts of rigour in 'rational analysis' itself, that there can in a plural society, be no guarantee of

any singular definitively prescriptive 'sound scientific' 'evidence-based', 'rational choice' of the kind so prominent in the rhetoric of many current energy policy debates. The point is not just that this is difficult to achieve. The notion itself of a uniquely 'science based' decision, is actually an oxymoron. So, the resulting implications are profoundly important for a host of social science methodologies that are very widely practised in policy appraisal in the energy sector. Risk assessment, cost benefit analysis, life cycle assessment, multi-criteria appraisal and decision theory, are all seriously compromised by their own deepest understandings of their intrinsic policy limitations [231,232]. The point is not that these methods are somehow entirely without value. They can still provide useful information – for instance, as a counterpoint to entirely unsubstantiated assertions like those excluding even reasonable possibility of particular energy alternatives [233]. But this value lies more in opening up appreciations of choice, than in closing these down [234]. When claims are made in energy debates (as elsewhere) to a single exclusively definitive 'evidence based' decision, they are (ironically and by exactly this claim) as plainly wrong as it is possible to be.

What emerges in turn from this, is that challenges of social choice like those with which this paper began, are inherently matters for explicitly political – rather than purely analytical – resolution [52,235]. More specifically, countervailing claims that such difficult questions can be fully resolved through calculative procedures of reductive aggregation or analytical optimisation are not merely difficult to realise in practice [235,236]. They are fundamentally meaningless even to aspire to – let alone claim. What is needed instead, where any political claims are to be made to democracy, are general qualities like openness, participation and accountability [237] – themselves typically made possible and sustained by active wider political mobilisation and robust critical debate.

In ways that are neglected in policy discourse, this deals a more general blow to increasingly technocratic and scientistic models for expert decision making in the energy sector, viewing rational choice as a matter purely of prescriptive analysis, without clear roles ***within particular policy areas*** for wider democratic institutions, inclusive practices or political discourse. A crucial role for social science in this area, then, is not merely to find ways to bolt itself on at the end of 'multidisciplinary' analysis in order to inform the most effective implementation of some prior ostensibly apolitically determined 'evidence based' energy policy. A key contribution for all kinds of social science lies also in helping to inform – and catalyse, provoke and mobilise – more vibrant political debate over the particular questions framings, values and knowledges under which alternative courses of action look most reasonable. As in more specific assessment methods discussed above, it is more in opening up room for such activity than in closing down around particular asserted understandings and commitments, that there lies the real contribution of interdisciplinary social science in general [234].

It is admirable – and ironic – that the rare degree of reflexivity involved in arriving at 'impossibility' results in social choice theory, should be achieved in a field generally disparaged by other branches of social science for a lack of reflexivity [238]. It is even more ironic, that the disciplinary communities who are most informed about these insights, should often remain so coy about more publicly acknowledging the policy implications [239,240]. This leaves the door unduly open to the use of 'evidence based', 'sound science' language as a cloak for much more partisan political agendas like those documented above around nuclear power or climate geoengineering. Either way, there is further important message here not only for social choice theory, but also for other branches of social science that have perhaps become complacent over their own claims to reflexivity. Qualitative, interpretive and constructivist social science (of a kind well established in the study of 'energy regimes') may also learn much about being prepared to admit more openly in policy debates, their own inherent limitations – and propensities for self-interested institutional suppressions of ambiguity and conditionality [15].

6. Sustainability and democracy

Beyond analytical procedures, however, roles for democracy are also subverted in other broader ways in current energy and climate policy discourse. General governance processes around 'Sustainability transitions', for instance, often display a degree of collective amnesia over the active forms of counter-power that made such radical aspirations a possibility in the first place [241]. Historically informed social science has an important role to play, in reminding how 'Sustainability' in general only became elevated to the highest levels of global governance as a result of protracted, radically challenging and overtly political struggles by subaltern social movements [169]. As well as pioneering many now-crucial organisational, technological and wider cultural innovations [242,243], it was these 'counterculture' interests that maintained continual pressure for diverse but interlinked imperatives around enfranchisement, emancipation, equality, ecology and nonviolence [100,244].

Yet – in energy policy debates as around Sustainability more generally – it is increasingly seen as self-evidently desirable that these creatively agonistic, fragmented and unruly arenas for civil society politics be structured into more consensual, integrated, orderly agendas for carefully designed 'sustainability governance' [245]. In a classic 'radicals dilemma' [246], ostensible rationales for this, lie in 'pragmatic' concerns over how best to effect transformative social and political change [247,248]. Yet – as shown by the early success of the Green movement (like sister movements for emancipation of classes, ethnicities, slaves, workers, colonies, women, young people and diverse sexualities) – there is an irony here [249]. In all these areas, it is in their more distributed and disorderly forms that subaltern social agencies typically affect their most formative influence [250,251].

In their more formally institutionalised forms, it is particular organisations and individuals within these movements that have often become susceptible to treating means as ends – pursuing strategic visibility, organisational positioning and reputational appropriation as proxies for earlier and generally more ambitious aims. Of course, this reflects the paradoxes of power and control outlined earlier (especially with regard to knowledge). So, the 'radical's dilemma' looks correspondingly more weighted towards co-option than challenge. Either way, it must at least be entertained that the securing of credibility in incumbent structures, is as much about responsively 'surfing' flows of asymmetric agency, as about proactively effecting more widely substantive transformative change.

This point is especially significant, since – explicitly or implicitly – much social science work around energy Sustainability has the effect of substituting rumbustious, holistic, explicitly normative, autonomous engagements by marginal interests [252], with tranquil, neatly segregated and formally orchestrated procedures of "polycentric governance" [253] – for instance in 'global assessments' with narrow topical remits driven primarily by experts [254]. Where wider civil society is involved at all, it is mostly through engagement of 'invited' (usually elite) 'stakeholders' [255]. And where social science contributions are seen primarily around this kind of instrumental delivery of 'social intelligence', 'consensus processes' or 'deliberative verdicts', there is a reflection in qualitative form of the same spurious kinds of closure committed in quantitative expert analysis reviewed above [234].

All the more important for being side-lined by these pressures for closure, then, a crucial role for social science emerges in rigorously setting out how all these processes – like knowledge production more generally – are inherently socially and politically situated. And this illumination of how incumbent interests can come to dominate the formal codification of policy knowledge, serves a very concrete positive function. It shows how transformation in the energy sector – like elsewhere – requires knowledges that are produced demonstrably independently from incumbent interests. This 'independence' is shown to stand most firmly, not in some romanticised single 'objective' position, but in multiple triangulations and counterpoints in pluralities of alternative equally valid interpretations, each with their associated constituting conditions [256]. In addition to offering a more robust basis for transformation, then, this 'plural conditional' approach to knowledge, also arguably offers better general prospects for genuine influence by excluded subaltern interests [257,258]. This kind of active 'opening up' of political space is disproportionately important as an active aim in social research in the energy sector as elsewhere – precisely because it is social science that shows how 'closing down' so often takes care of itself [234].

But the established emphasis of social science in energy studies lies rather far from this. Indeed, the patterns of instrumental closure discussed above sometimes penetrate most deeply, in the apparently most progressive of social research on 'Sustainable energy transitions' [15]. It is remarkable, for instance, given the diversity of political drivers mentioned above, how often the complex breadth of "Sustainability" – canonically highlighted by the Brundtland Commission around social equity, human and wider ecological integrity [259] – tends to contract to a single "low carbon transition" alone [11,260–267]. This 'political pyrolysis' of Sustainability (a reduction simply to carbon), compresses the open-ended, multiplicity of values and issues, into a single ostensibly one-dimensional technical metric [268]. And these processes of technocratic reduction are even further compounded where the plurality of possible 'transformations' are further compressed into 'the' (supposedly singular) 'transition' – a closure further reinforced by the assertive definite article [15]. There is little room here for politics, let alone democracy. And the role of social science risks reduction to that of public relations [269,270].

This said, Sustainability in general, does in many wider areas of international energy governance retain a greater diversity of dimensions. This is the case, for instance, around the 'Millenium Development Goals' process [271,272]. But even this potentially more plural political space is itself subject to powerful current reductions. Despite efforts to soften the compression to technical parameters alone [273,274], the recent prominent 'planetary boundaries' initiative in 'Sustainability governance' accepts only material metrics to qualify as defining the "operating space for humanity" [275]. That this is a technical – rather than political – domain, is emphasised by the strictly delimited supposedly "non-negotiable" status of these "planetary boundaries" (276:31). Insistence on "absolutely no uncertainty", brooking "no compromise" [277] reinforces the technocratic message, further undermining appreciation of the scope for wider ambiguities, trade-offs and contending values. So, the space for social science, politics and democracy alike are all seriously reduced.

To be fair, however, complexity and indeterminacy do play roles in this discourse. But, in a contradictory twist, the main ways these are expressed are as "catastrophic tipping points" [278]. By asserting these with paradoxical confidence not as indeterminate possibilities but as determinate "boundaries", it is as if they are precisely known [275,276]. Thus are complexity and uncertainty domesticated under an elaborated discourse of control. And the space for politics is further confined, by the impression that these 'boundaries' render the Earth itself static and brittle. The crucial political point risks being lost: that it is particular ***kinds*** of human societies that render disadvantaged people vulnerable; that this occurs even under the ***most favourable*** of environmental conditions; and that the most likely dynamics of transformation lie in ***hope-inspired alternative choices***, not fear driven technical constraints.

Far from this, the 'planetary boundaries' discourse goes even further in homogenising human agency and responsibility. The undifferentiated singularity of humanity in the central concept of 'the Anthropocene', strongly undermines appreciation that the issues lie more in diverse and dynamic possibilities for alternative different societies and economies, rather than in degrees of technical compliance with supposedly fixed environmental boundaries [279,280]. That the Anthropocene is also defined in terms of 'domination' [281–283] of the Earth by this supposedly seamless 'humanity' [284], reinforces discourses of control and compounds their de-politicisation. With latitude for political debate – let alone democratic accountability – thus even more seriously eroded, this starkly imperative discourse fuels the desperate fallacies of control discussed above around climate geoengineering. Where 'Sustainability' is addressed like this as a determinate technical end, rather than as an empowering democratic process for determining plural human and ecological ends, then it betrays its own foundations [268,285].

7. Social science implications

The key challenges presented by these developments for social science seem clear. These lie in moves away from defining Sustainability in general – and Sustainable energy in particular – exclusively in terms of outcomes. Social research is as much about the processes and directions of change through which understandings and developments do or don't unfold, as about any goals and end-points in themselves. Crucial here is a key neglected theme in Brundtland's original characterisation of Sustainability – emphasising needs for "effective citizen participation" (259:16;58) and "greater democracy" (259:16). This was emphasised not just as a means to decide detailed modes of implementation, but to resolve the meanings of Sustainability itself. If the social science of energy is to take Sustainability seriously, then this is the sense in which it must be meant. And if social research is to claim any alignment with these goals, then democracy itself – in all its many plural, ambiguous and uncertain forms – is not only a central analytical focus but a pivotal normative commitment.

And it arises from the preceding argument, that diverse aspects of democracy are as important in the constituting of robust knowledge, as in implementing any associated actions. But this is where a further particular problem becomes evident in social research for energy transformation. In ways such as those exemplified above, too much contemporary social science in this area invokes 'Sustainability' as if the meaning were so obvious that it can remain unstated. Similar non-specificity in the advancing of interests like 'sustainable business' or 'sustainable profits', can lead to highly instrumental manipulation [286]. So, in the rush to effect a supposedly singular self-evident 'Sustainability transition', it often remains under-explored exactly what 'sustainable energy' might actually mean. And this is especially true of the plural social processes through which the disparate meanings and enactments of 'sustainable energy' will be diversely experimented and understood.

Of course – whether deliberately or not – much public engagement activity in the energy field highlights exactly these issues

[287–289]. But it remains the case that this is often quite incidental. Rather than seeking explicitly, systematically and as a priority, to advance wider critical politics and democracy, much social research for policy analysis in this field, restricts experimentation in 'public engagement' to the securing of instrumental forms of closure. Yet more prominent than democratisation in many of these initiatives – especially in funding bids – are incumbent imperatives to: justify decisions [28]; command authority [290]; foster trust [291]; build legitimacy [292]; manage blame [293]; secure acceptance [294]; or even administer "sedation" [295]. So, it is here that a final normative implication for social science becomes most clear: to help enable the more vigorous, equitable and inclusively critical democracy envisaged (for instance) by Brundtland. And this is as important with respect to the meanings of 'Sustainability' itself, as to understandings of the most appropriate practices and innovations through which to achieve it in the energy domain.

It is in these politics of knowledge, that social science in the energy field – as elsewhere – encounters one of its own deepest, most intractable and distinctive features: the "double hermeneutic" [296]. Knowledge in general is socially produced. And this includes knowledge about society and its energy possibilities. So, alone among the natural scientific and engineering disciplines which otherwise dominate the field of energy and Sustainability research, social science is distinguished by the fact that subjective conditions of enquiry are not only directed at objects of interest, but also form part of that object. And what this means in turn, is that – without deliberate counterbalancing efforts – the social orders that typically impact most strongly on the production of knowledge, can end up as those that are already incumbent within this setting [57].

Recognising this, is often uncomfortable. It can be especially underappreciated in interdisciplinary initiatives, where their lack of 'double hermeneutic' dilemmas mean that natural sciences and engineering are typically able much more readily (though no less spuriously) to pretend at objective detachment. And where social science attempts to acknowledge this discomfort, the problems are further compounded. Efforts at 'opening up' the implications of alternative values and interests are often rejected as impossibly inexpedient to decision making. Ironically, this can lead positions that are otherwise most apparently positive about 'natural realities', also to be those most prone to subordinating these 'real world' complexities and indeterminacies to politically driven simplification and closure [256]. Even more ironically, it is rare occasions where social science attempts to escape this politically driven bias and closure, that it tends to be most criticised as inappropriately partisan. Like iron filings in magnetic fields, the contours of neutrality in a world without objectivity, are taken to align with whatever are the most powerful proximate interests.

Instead of challenging this, and explaining the obvious salience of the double hermeneutic, much social science in the energy field seems to prefer to try to don the same objectivist body language as the other disciplines with which it is engaged. Economics, social psychology, political science and sociology alike all often tend to ignore the resulting conditioning effects of particular institutional or disciplinary normativities on their own associated understandings. The resulting knowledges are treated as if objectively synoptic [297]. So, if there is an aspiration to greater consistency and rigour than this, then tacit denial of normativity must be replaced with explicit declaration. Only in this way, may interpretive qualitative understandings achieve the qualities of plurality and conditionality highlighted above as also desirable for quantitative analysis. Without these qualities, social science may itself be judged as further complicit in the wider processes of attenuation of democracy.

This means that a balanced role for any social science that seeks to be aligned more generally with progressive (for instance, Brundtland-style) visions for democracy, lies not merely in 'opening up' understandings of the implications of otherwise-marginalised perspectives [298]. The aim must also be much more deliberately and directly to critically ***resist*** the forces of closure [299]. That such a balanced and reasoned aspiration in academia should so often be caricatured as inappropriately normative, is itself an indication of the salience of democratic aims. Rather than pretending that power relations have no bearing on knowledge production, this explicitly and actively democratic approach simply means being more rigorous about this indisputable social fact.

The essence of a democratic social science in energy studies, then (like democracy in general), lies in constant struggle, of multiple kinds, to counter these kinds of dynamic. Romanticised notions of transcendent neutrality are manifestly fictive. Even as aims, they are (through tacit denial of the double hermeneutic in social understandings), potentially corrosive of democracy. So, the point is not one of striving fully or finally to eradicate what social research repeatedly teaches may in many ways be intrinsic (or unavoidably circumstantial or emergent) asymmetries of agency. And the message need not even be that a particular concentration of power is somehow inherently bad. The issue instead, is that all the many forms of power – and their associated kinds of closure – may confidently be expected to take care of themselves. So, any broadly democratic purpose in social research (as outside), lies not in some particular notional outcome, but in a never-ending and ever-provisional struggle to reduce these asymmetries of agency as much as may reasonably be achieved in any given context.

8. Reflexive transformation

Whether they are agreed with or not, the considerations raised in this paper relate not only to social research around energy systems, but to social science in general. In this, the points made here seek to substantiate the argument with which this paper began, that the momentous current circumstances bearing on global energy choices are not only crucial in their own right, but also offer a potentially formative locus for addressing issues and forces of much wider political importance. And these relate as much to the configuring of formative ***knowledges*** about society, as to the material constituting of ***society itself***. So, for any kind of democratic sensibility, a key problem lies in the powerful general pressures (documented here specifically in relation to energy transitions), that can act to suppress serious discussion of these wider and deeper issues and forces. Drawing on deeper themes in politics and social science, then, the paper will end with a series of specific normative principles. These will be intended as heuristics, if not to guide, then at least to help catalyse and provoke more active and explicit attention.

It will not escape the reader's attention, however, that to make such attempts here at concrete prescription, seems to incur its own contradictions. What of the earlier call for reflexivity? Does this not compel never-endingly recursive qualification, in continual regress away from clear positive implications for action? The short answer is 'no'. The analysis above pointed not to the suppression of normativity, but to the need for more explicit declaration – even celebration. Criticising scientistic claims to singular definitive objectivity, does not mean rejecting the taking of positions. Instead, it was argued that reflexivity brings a responsibility to represent knowledge and its implications in 'plural and conditional' ways. And – in recognising how knowledge is shaped by power – reflexivity also challenges the conventional sequencing of knowledge as prior to action. Interventions by social research concerning energy transformation, are (whether acknowledged or not) about political action as much as about academic understanding.

In this sense, prescriptive recommendations such as those made here are entirely reasonable in social science. But they are only reflexive in the democratic senses outlined above, when they openly explore their own underlying formative epistemic and normative conditions. In the present article, then, these driving motivations have been explained to lie in a relational understanding that substantive transformations in any given area like energy, are possible only through the transforming of power itself. It has been argued that this entails in turn a commitment to continual democratic struggle against the effects of concentrated power – in knowledge as much as in more material social structures.

So, this form of reflexivity is not some transcendent 'vertical' "virtue", locatable in individual social actors [300]. As elaborated elsewhere [301], it lies arguably instead in many horizontally distributed social fields of turbulent relational flows. In short, reflexivity is as much about action as knowledge. And, in this view, the social science of energy is – like other research – a particular kind of social action. So, associated normative and epistemic commitments (implicit or explicit) are not antithetical to reflexivity, but – in appropriately democratic wider contexts – provide the formative (though ever-provisional) fulcra for catalysing the counter reactions. Indeed, it is this distributed, uncoordinated, agonistic but mutually co-constituting cycle between commitment and reaction that arguably best characterises social reflexivity.

The role for aspiringly transformative social research on energy, then, lies not in seeking to court the patronage of proximate power, by "seeing like a state" [38]. The analogy is perhaps more with the dynamics of social movements. Here, the "*strategic essentialism*" of campaigning organisations provides "the simplified political representations that social movements must generate to cohere" (302:5052,303). These may sometimes amount to little more than 'civilising hypocrisies' [304]. But the associated interplay of many kinds of knowledges, values and interests remains explicitly situated in social action. It is arguably only through this kind of dynamic, rather than the orderly structures of 'evidence based policy', that diverse societies worldwide, may truly hope to help catalyse the kinds of collective reflexivity necessary for substantive (rather than rhetorical) global energy transformations.

Returning at the end, then, to the themes around power with which this paper began, substantive (rather than superficial) transformation is not – for reasons given there – achievable through 'control'. The subverting dynamics of power discussed throughout this paper, simply accentuate this. And the implications are especially important for social constituencies that are as typically marginal to incumbent concentrations of power, as is the case of most energy transitions researchers. For these, the above picture of the progressive potential of social reflexivity, suggests instead that substantive transformation is better achieved through care, rather than control [305]. And what specifically needs to be cared for, are wider democratic capacities for scepticism, openness, participation, accountability and critical dissent [237] – such as to allow the necessary transformative reflexivity to thrive.

Where action is acknowledged to shape knowledge, but knowledge to constitute action, social science interventions are accountable in both ways – as hybrid 'knowing doings' [306]. And if the aim is substantive (rather than superficial) transformation, then they should not seek to imitate the synoptic pretensions and fictive aspirations of incumbency to control. They are best enacted instead in more modestly subaltern ways, as 'Trojan horses' and 'political judo' [15] of kinds whose effects lie not in their own direct purported force, but in the wider reflexive reactions. This is like the flocking behaviour of animals, or the dynamics of culture more generally – an arena for some of the most radical, rapid and transformative forms of social change. So it is arguably through reflexively democratic 'culturing' of transformative change [307], rather than by more 'managing' forms of governance, that genuinely substantive energy transformations face their greatest prospects for hope.

9. Knowing doing transformation

It is in this heuristic, reflexive and aspiringly catalytic spirit of distributed 'knowing doing', then, that this paper is offered. The following recommendations are voiced not as transcendent 'evidence' from supposedly apolitical 'integrated' analysis. Instead, they are much more provisional, situated reactions to the particular political dynamics in which they are embedded. Whether as 'trojan horses', 'political judo' or 'civilising hypocrisies', then, there emerge a series of concrete implications for the 'culturing' of energy transformation. Though much latitude remains for interpretation, each principle is conditional on the explicitly normative position articulated earlier – in favour of emancipatory democracy as the only genuine means to achieve progressive social transformation [308]. If social science is to support transformations of this kind in Sustainable global energy infrastructures, these principles may prove correspondingly important.

- The roles of social science in interdisciplinary energy research, are not just about the social complexities encountered in pursuing goals driven primarily by natural science or engineering. Social research also assists in framing priorities, questions and options for these other disciplines – in turn informing its own driving aims and those of society more widely.
- Aspirations (still more, claims) to singular uniquely prescriptive 'sound scientific' or 'evidence based' findings are as misleading in the social science of energy as in other fields. This is as true of interpretive appreciation and participatory deliberation as it is of quantitative analysis. A responsibility not to mislead, confers an obligation not just to avoid, but also to deconstruct these forms of justificatory closure.
- So, social science should therefore not only refrain from, but actively critique, policy recommendations presented in singular prescriptive ways. Instead, it should convey to policy making and wider political debates an explicit and symmetrical plurality of social interpretations of energy alternatives, each equally valid under different reasonable perspectives – carefully explicating with each, its associated constituting conditions.
- And in these interests of more balanced understanding, energy social science should also interrogate the processes for closure in which it is itself located, which enforce the practices of justification. This includes challenging how specific reduced understandings arise of 'Sustainability', 'transitions' and 'planetary governance' – and showing how these favour and suppress particular political interests and implications.
- This in turn entails that social science in service of democratic energy politics should be open and reflexively self-critical about its own subjectivities – whether these be shaped by theoretical frameworks, methodological styles, disciplinary interests or expert community values. It is a matter of rigour, then, that social science should in this way help 'open up' (rather than 'close down') the space for robust wider policy debate.
- Where values are openly declared, broadly democratic (rather than merely disciplinary) aims in energy social science research, must seek not only to reverse tendencies to closure, but strongly to resist the shaping of knowledge by incumbent interests. It is thus a matter of rigour as much as democracy, actively to help

rebalance marginal interests, redistribute privilege and enable choices benefitting the less powerful.

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